QI Petrophysics

Seismic Petrophysics

Well Logs to Wiggles

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Seismic Petrophysical Analysis and Rock Physics Characterization

Seismic Petrophysical Analysis^{TM} is defined as well log interpretation backed by rock physics principles, for well log and seismic integration for seismic reservoir characterization. This unique approach allows for the integration of wellbore data and seismic data in the context of rigorous quantitative interpretation of a given seismic volume. This analysis focuses on the entire well depth to derive the best set of well logs for quantitative interpretation. Moreover, ***Seismic Petrophysical Analysis*** (***SPA***^{TM}) utilizes rock physics fundamentals, and relationships to create a robust data set that can be used for acoustic forward modeling as well as perturbational rock and fluid modeling.

Seismic Petrophysical Analysis includes editing of shallow investigating tools (density and sonic curves), environmental corrections, derivation of volumetric curves for lithology and water saturation, identification of mud filtrate invasion, corrections of invasion in reservoir units (Walls and Carr 2001, Carr et al 2004), ***Rock Physics Characterization***, calculation of elastic curves from rock physics modeling, and multi-well trend analysis. The results of the ***SPA*** workflow are a set of well log curves that will likely produce a robust and consistent elastic response for integration with a seismic volume. A key component of ***SPA*** is the ***Rock Physics Characterization***^{TM} ***(RPC)*** procedures, which allow for the definition and derivation of Effective Medium Models that best describe a given facies. However, the main goal of relating petrophysical variation with elastic response requires that the measured data to be interrogated, and not simply replaced by a model value. ***RPC*** is a method of investigating the link between measured petrophysical properties of reservoir as well as non-reservoir rocks, and the correlative elastic response in the context of fundamental rock physics principles. The ***RPC*** approach allows for the examination of the original unedited data as well as the multiple empirically derived values in both the well log domain and the cross plot domain. Once the appropriate model is either determined or derived for each facies, those models can be used as a predictive tool to replace obviously bad data with relevant modeled values.

V_S Estimation

To create a synthetic seismogram for integration of well log data and a seismic volume, continuous density (*RHOB*) and compressional velocity (V_P) curves are minimally required (zero offset synthetic). Continuous shear velocity (V_S) is additionally required for creation of a full offset synthetic. The curves required for synthetic modeling are generally shallow looking devices and thus impacted by bore-hole effects (wash-out, invasion, etc.). Therefore, editing of the measured data is required to produce values that are consistent with the lithology present, the geologic setting, age, reservoir temperature, reservoir pressure, and fluids present at any given depth. Additionally, the shear velocity (V_S) curve many times was not recorded (none before 1992), or many times possess erroneous values. Many different effective medium shear estimators are available from the literature. Dr. Carr calculates several V_S curves for each well using multiple published and proprietary algorithms. The estimator deemed best for the given geologic setting is then chosen. Once the values for *in situ RHOB*, V_P, and V_S are continuous over the entire well depth, acoustic forward modeling and perturbational rock and fluid modeling can be performed.

Perturbational Rock and Fluid Modeling

In most projects the wells available do not completely represent all of the geologic variation that might be expected in any given zone of interest. Thus geologically relevant, physically possible models are derived. The models are generated to represent the natural inter-well variability that may be present in the subsurface, but was not sampled by the wells. In this case ***Perturbational Rock and Fluid Modeling*** is employed, specific to each project. For example the sampled reservoir zone could possess reservoir brine rather than the desired hydrocarbon, thus fluid substitution would be employed. In another possible scenario the sampled well may possess porosity values below an economic cutoff, where porosity modeling would be used, to examine the effect of increased porosity on the elastic response of the reservoir. Dr. Carr applies a holistic integrated approach, grounded in rock physics principles, to provide the solutions that best fit each customer and the specific project need.

AVO Modeling

In many projects where the offset data in the seismic volume possesses information regarding presence of fluid type, ***AVO Modeling*** is required. To examine the effect of fluid saturation on the reflection at a single interface, Half-Space models are constructed. A Half-Space model is the simplest model that can be employed to examine the elastic response of a given reflection event. In practice the Half-Space models are constructed by obtaining the average V_P, V_S, and *RHOB* in a given sand body, for each of the different fluid saturation scenarios, as well as the average V_P, V_S, and *RHOB* for the above bounding shale body. For each fluid saturation scenario a linear approximation of the Zoeppritz (1919) equations are solved. The results are given as the Intercept and Gradient for each case, as well as plotted as reflection coefficient as a function of angle. This simple model allows for insight into how the rock properties will manifest in the offset domain. The information gleaned from the Half-Space models can be invaluable to interpreters as they prospect for hydrocarbons. Although the Half-Space models can be very useful, a more rigorous full space model is also generated in the synthetic seismogram.

Synthetic Seismic Modeling

The main goal of **Seismic Petrophysics** is to produce a synthetic seismogram that will produce a robust representation of the subsurface in the elastic domain. The seismogram should reasonably tie the seismic volume with a minimum of additional manipulation, given the correct spatial location, frequency content, offset parameters, etc. **Dr. Carr** works closely with his clients to generate the most consistent and robust elastic models, not only for the *in situ*, but also for the perturbational models. These synthetic seismograms can input into synthetic attribute calculators, used in neural network algorithms, and to ultimately calibrate a seismic volume in terms of rock and fluids. The unique ***Seismic Petrophysics*** workflows developed by **Dr. Matthew Carr** allow for consistent, robust well log data set that can be confidently applied for seismic reservoir characterization.